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(54) Line-by-line photocopying

(57) A line-by-line photocopier employs a short conjugate length optical scanner in the form of sets of objective, field and projection lenses 13 in three respective arrays 10, 11 and 12, the lenses being aspherical converging lenses of equal focal length, each array comprising two staggered rows of lens, and a honeycombed aperture structure being situated between each pair of lens arrays, each aperture being of square cross section with a diagonal at right angles to the direction of scanning.

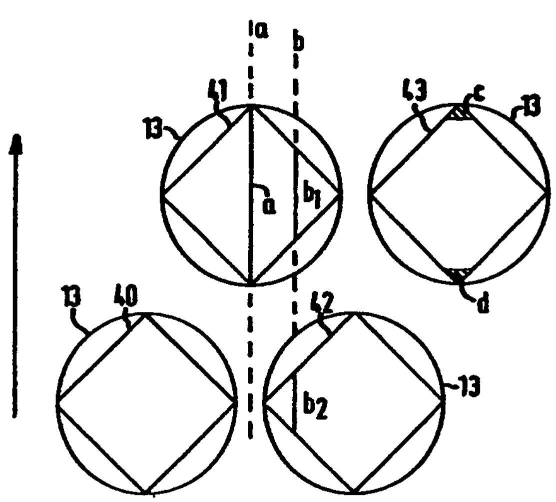

FIG. 7

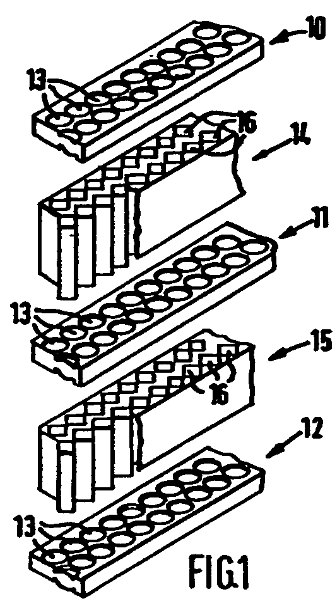

FIG.1

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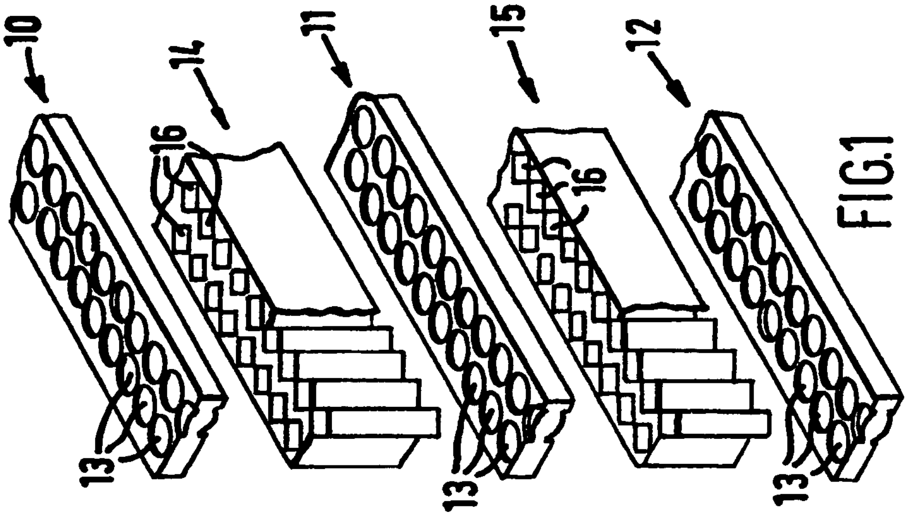

FIG.1

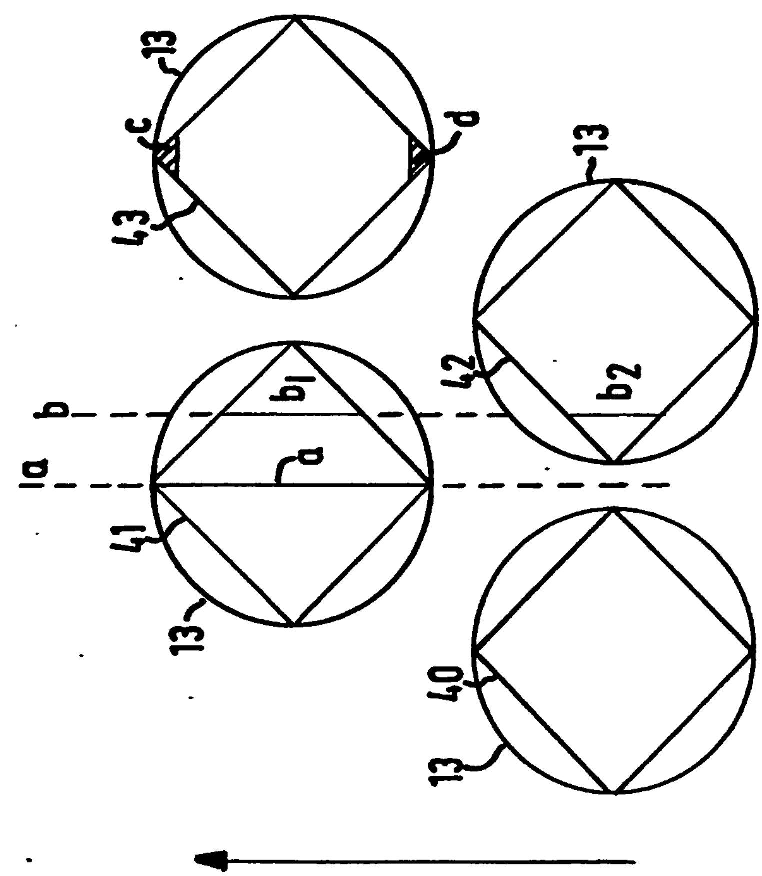

FIG.7

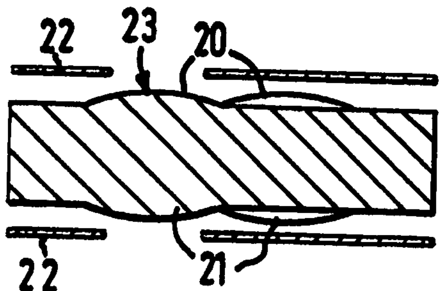

FIG. 2

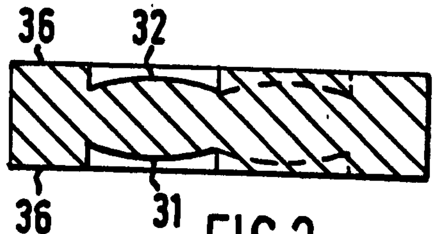

FIG.3

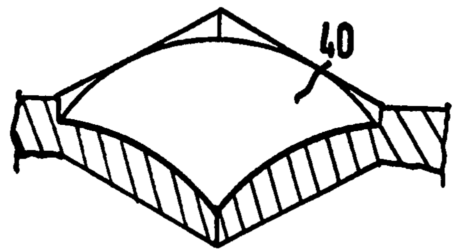

FIG.4

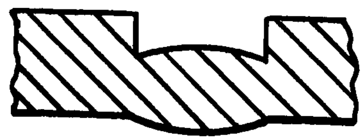

FIG.3a

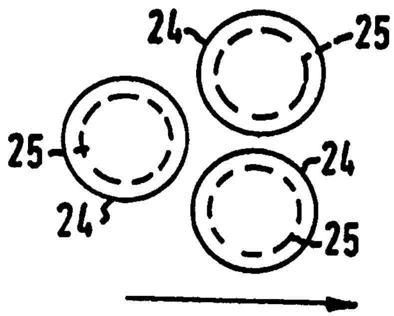

FIG.5

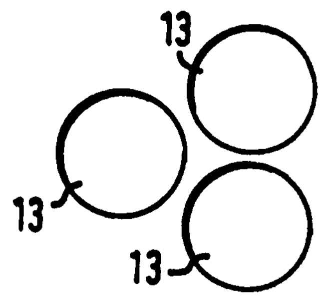

FIG. 6

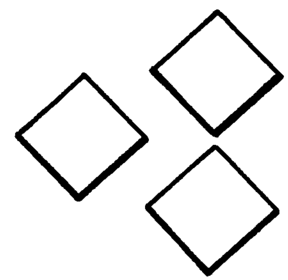

FIG.8

SPECIFICATION

Optical device for electrostatographic copying and duplicating machines

The present invention relates to an optical scanning device principally for use in forming an image of a document or other article to be copied or duplicated stripwise onto an electrophotographic recording member.

US Patent Nos. 3584950 and 3584952 (R. W. Gundlach, assigned to Rank Xerox Corporation) and UK Patent No. 1200383 (Rank Xerox Limited) described an optical scanning device for use in electrostatographic copying machines which was of very short conjugate length and which cast an upright wrong reading image of a document to be copied onto a re-usable electrostatographic recording member. The device employed three optical strips of moulded plastics material each formed with two rows of convex lenses, the strips being fitted in superimposed relationship in a housing. The lenses in the three strips were in optically aligned relationship. Each set of three aligned lenses had an objective, a field lens and a projection lens and each set of lenses scanned a discrete elemental area of the document to be copied and produced an image of that area on the electrostatographic recording element, scanning movement of the strip relative to the document producing a composite image of the document on the recording element which is held stationary relative to the document being scanned. But the devices there described used spherical lenses which required aperture stops for the objectives to limit the angle at which light could enter the objectives of each lens group in addition to a field stop to define the field of view of the lens group. Only the central part of each objective lens was being used. Furthermore, spherical lenses had to be of relatively long focal length in order to give an acceptably sharp image. These problems increase the space requirements and manufacturing cost of a device which is intended to be small and inexpensive.

The present invention provides a short conjugate length optical device for projecting light rays from an object plane to an image plane, comprising first, second and third strips of transparent material each similarly formed with a multiplicity of aspherical converging lenses of equal focal length positioned in two parallel rows along the strip one row behind the other with the lenses of the second row staggered one half spacing with respect to the lenses of the first row, the first second and third strips being disposed at equal spacings one behind the other so that their lenses optically cooperate in sets with the optical axes of the lenses of each set in alignment, the first strip being nearest the object plane, the second strip being located in the plane of an intermediate image formed by the first strip and acting as a light collector and the third strip serving to project the intermediate image onto the image plane, each optically cooperating set of lenses viewing a discrete area of the object and casting onto the image plane a generally square light field with a diagonal directed at right angles to the longitudinal direction of the strip and in contiguous non-overlapping relationship with adjoining light fields of other optically cooperating sets of lenses, the arrangement being such that an off-diagonal portion of one light field of a set of lenses of one row is in transverse alignment with a complementary portion of a light field from the adjoining set of lenses in the other row so that scanning movement of the device in the direction transversely of the strips builds up a continuous image of the object plane with only minor variations with position along the strip in total amount of light reaching the image plane.

One advantage of using aspherical converging lenses which produce a focused image in a common plane independent of distance at which the light impinges on the lens and the optical axis is that shorter focal length lenses can be used and the device can be made more compact. Furthermore there is no need for an aperture stop on the objective and the whole of the objective lens is in effective use. the arrangement where square light fields disposed in two rows in non-overlapping complementary relationship are projected onto the image plane has also been found to be particularly effective in combination with the use of aspheric lenses because when the object plane is scanned the image reaching the image plane is sufficiently uniform for most common electrophotographic purposes and in particular for the copying of typewritten or printed documents.

In a preferred construction one honeycomb element extends between the adjacent faces of the first and second strips and another honeycomb element extends between the adjacent faces of the second and third strips, the cells in the honeycomb elements defining discrete light paths through the sets of lenses in the device. The shapes of the honeycomb cells can advantageously be used to define the shape of the light fields projected by the sets of lenses. Thus lenses whose faces are on the form of solids of rotation and which have circular peripheries can be used in association with honeycomb elements whose cells are of square cross-section to give the appropriate pattern of square non-overlapping light fields. In an alternative construction the light fields projected by the sets of lenses can be defined by the shapes of the lenses which are generally square in plan.

The lens strips which have hitherto been suggested for use in strip lenses of the present kind have all incorporated generally planar biconvex lenses whose curved surfaces protrude from the major planes of the strip. We have found that a simplified construction results from moulding the lens strips in plastics material with the curved face (in the case of monoconvex lenses) or each curved face (in the case of biconvex lenses) recessed relative to the major faces of the lens strip. In order to prevent light passing through the non-effective planar portions of the lens strip a foil of opaque material can be hot

The drawing(s) originally filed was/were informal and the print here reproduced is taken from a later filed formal copy.

stamped onto the or each face of the lens strip and the unadhered regions of the foil can be broken off at the sharp lens boundaries to reveal the underlying lens. There is therefore no need to incorporate a separate, accurately made, aperture plate to define the fields of view of all the lenses of the strip.

The invention further comprises an electrostatographic copying or duplicating machine having a movable document table defining an object plane, a rotatable drum carrying in electrostatographic recording element and defining an image plane, the document table and the drum being arranged for synchronised movement in the same direction during scanning of the document to be copied, and a short conjugate length optical device as aforesaid for casting an image of a document on the document table stripwise onto the drum during rotation thereof. The optical device is intended to cast a 1:1 upright wrong reading image onto the drum, in which case means is provided to develop a resultant charge on the electrostatographic element (which is a re-usable selenium coated drum, zinc-oxide coated paper sheet supported on the drum or the like) and means is provided to transfer the developed toner image from the drum onto the copy sheets.

Various embodiments of the invetion will now be described by way of example only with reference to the accompanying drawings, in which:

Figure 1 is an exploded view of the working components of the strip lens of the invention;

Figure 2 is a view in transverse section on an enlarged scale of a strip of lens material according to the prior art;

Figure 3 is a similar view of a strip of lens material used in the strip lens of the invention;

Figure 3a shows a slightly modified version of the strip lens;

Figure 4 is an oblique fragmentary view of an alternative form of a strip of lens material partly cut away to show the lens formation;

Figures 5 to 8 are diagrams depicting lens arrangements and the resulting image plane light fields.

As is apparent from Figure 1, the strip lens consists of upper, intermediate and lower lens strips 10, 11, 12 which are moulded in transparent plastics material and are each formed with a multiplicity of lenses 13 disposed in two rows parallel to the longitudinal direction of the strip with the lenses in each row very close together so that they almost touch and with the lenses in the two rows also almost touching. One row of lenses is staggered one half lens spacing or pitch with reference to the lenses in the other row. A honeycomb structure 14 is interposed between lens strips 10 and 11 and another honeycomb structure 15 is interposed between the lens strips 11 and 12. Open passageways or cells 16 in the honeycombs 14, 15 are spaced in conformity with the spacings of the lens elements 13. The honeycombs 14 and 15 may be formed of black plastics material or they may be an aluminium extrusion cut to length and optically blackened to minimise stray reflections of light. The strip lens is assembled with the lens strips 10, 11 and 12 in superimposed relationship such that the individual lenses 13 have their optical axes aligned. Thus light will pass from an area of an object being scanned to a lens 13 of strip 10 which acts as the objective. It then passes through one cell of honeycomb 14 to the underlying lens 13 of lens strip 11 which acts as a light collecting lens. The aperture defined at the central light collecting lens serves to define the field of view of each set of lenses in the array. The light then passes through one cell of honeycomb 15 to a lens 13 of lens strip 12 which acts as a projection lens and casts a 1:1 image of the object onto an underlying re-usable photoconductive recording element which may be a selenium drum or a sheet of zinc oxide paper supported on a drum as is well known in the electrophotographic copier art. The individual components of the strip lens are mounted in a frame (not shown), optionally between clear flat sheets of plastics material to protect the outer faces of lens strips 11 and 12 from dust and to provide an easily cleaned surface.

A conventional formation for the lens strips 10, 11 and 12 is shown in Figure 2. Biconvex lenses are defined by protruding convex surfaces 20 and 21 and the lens strip is associated with one or more plates 22 formed with apertures which are shaped to define the field of view. The lens boundaries 24 and light fields 25 are shown in Figure 5, from which it is apparent that the lenses are stopped down so that they are not fully utilised. Also, when the lenses are scanned in the direction of the arrow, the light fields (which are discrete and circular and which do not overlap) build up a composite image involving the use of either one lens or two adjoining lens groups depending upon the transverse position in the array. But the way in which the adjoining lens groups register in the scanning direction does not give an even distribution of light along the strip. Furthermore, the provision of separate plates 22 to define the fields of view is essential because it is difficult to coat the non-effective flat regions 26 of the strip selectively by reason of the protruding biconvex regions.

In Figure 3 the lens surfaces 31 and 32 are depressed below the major faces 36 of the lens strip and define an aspheric converging lens such that light incident on all regions the lens including its periphery are brought to a sharp focus in a common plane the distribution of the lenses and hence of the light fields produced (in the absence of anything defining the field of view) is shown in Figure 6. But it is apparent from Figure 1, the cells 16 in the honeycombs 14 and 15 are square in section with one diagonal directed transversely. The effect of this combination of circular lenses with square obliquely directed cells is shown in Figure 7. Separate light fields 40, 41, 42 and 43 are shown, and the arrow denotes the scanning direction. Along diagonal a, and close to it, only a single lens group is involved in formation of the composite image. Along the off-diagonal line b, the image is formed additively by elements b_1 and b_2 of the light fields produced by adjoining lens groups in different rows but the length b_1 and b_2 is close to the length of the diagonal a in the region where the two light fields are in register. Thus there are only minor variations in the total amount of light reaching the photoconductive

recording member. Many copying applications involve the reproduction of written information or line drawings or the like, where the image is black or white rather than half-toned and such images are relatively insensitive to small variations in the amount of light reaching the recording member. Even less variation in light intensity can be produced by removing or rounding-off the leading and trailing corners of each light field (ie. the shaded areas c and d in Figure 7) so that the length of light field which traverses any given point on the recording member is substantially independent of position along the lens strip.

In Figure 4 the lens 40 is defined by a square periphery and the corresponding light fields are shown diagrammatically in Figure 8. With this lens arrangement, the honeycombs are retained but their individual cells can be of cross-sections other than square.

It will be appreciated that various modifications can be made to the invention, the scope of which is defined by the appended claims. Thus, Figure 3a is generally similar to Figure 3 except that one lens surface is depressed below one major face of the lens strip whereas the other lens surface projects from the other major face.

CLAIMS

1. A short conjugate length optical device for projecting light rays from an object plane to an image plane, comprising first, second and third strips of transparent material each similarly formed with a multiplicity of aspherical converging lenses of equal focal length positioned in two parallel rows along the strip one row behind the other with the lenses of the second row staggered one half spacing with respect to the lenses of the first row, the first second and third strips being disposed at equal spacings one behind the other so that their lenses optically cooperate in sets with the optical axes of the lenses of each set in alignment, the first strip being nearest the object plane, the second strip being located in the plane of an intermediate image formed by the first strip and acting as a light collector and the third strip serving to project the intermediate image onto the image plane, each optically cooperating set of lenses viewing a discrete area of the object and casting onto the image plane a generally square light field with a diagonal directed at right angles to the longitudinal direction of the strip and in contiguous non-overlapping relationship with adjoining light fields of other optically cooperating sets of lenses, the arrangement being such that an off-diagonal portion of one light field of a set of lenses of one row is in transverse alignment with a complementary portion of a light field from the adjoining set of lenses in the other row so that scanning movement of the device in a direction transversely of the strips builds up a continuous image of the object plane with only minor variations with position along the strip in total amount of light reaching the image plane.

2. An optical device according to Claim 1, wherein one honeycomb element extends between the adjacent faces of the first and second strips and another honeycomb element extends between the adjacent faces of the second and third strips, the cells in the honeycomb element defining discrete light paths through the sets of lenses in the device.

3. An optical device according to Claim 2, wherein the peripheries of the lenses are circular and the light fields projected by the sets of lenses are defined by the cells in the honeycomb elements which cells are of square cross-section.

4. An optical device according to Claim 1, wherein the light fields projected by the sets of lenses are defined by the shapes of the lenses which are generally square in plan.

5. An optical device according to any preceding claim, wherein the converging lens has one or both faces curved and one or both of the curved faces is recessed relative to the respective major face of the lens strip.

6. An optical device according to any preceding claim, wherein one major face of each lens strip has adhered thereto a layer of material which is opaque to light in regions between recessed curved lens faces.

7. An optical device substantially as hereinbefore described with reference to and as illustrated in the accompanying drawings.

8. An electrostatographic copying or duplicating machine having a movable document table defining an object plane, a rotatable drum carrying an electrostatographic recording element and defining an image plane, the document table and the drum being arranged for synchronised movement in the same direction, and a short conjugate length optical device as claimed in any of Claims 1 to 7 for casting an image of a document on the document table stripwise onto the drum during rotation thereof.

9. An electrostatographic copying or duplicating machine as claimed in Claim 8, wherein the optical device is arranged to cast an upright wrong reading image onto the drum, means is provided to develop a resultant charge with toner, and means is provided to transfer a developed toner image from the drum onto copy sheets.

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